The Institute of Physics

BULLETIN

SEPTEMBER 1956 · VOL. 7 · No. 9

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Notices to Members

Presentations to Dr. B. P. Dudding and Sir George Thomson

Dr. B. P. Dudding will retire on September 30 from the office of Honorary Secretary of the Institute in which he has served for ten years since he succeeded the late Professor J. A. Crowther. The Institute is deeply indebted to Dr. Dudding for the great care and attention that he has given to its development in the difficult post-war years. On July 17, following the last Board meeting of the 1955-56 session, a small dinner party was held at the Institute's House at which the President presented to Dr. Dudding an antique clock that had been bought for him by past and present members

Sir John Cockcroft (left) and Dr. Dudding.

The dinner held in honour of Dr. Dudding and Sir George Thomson.

Those present are : on the outside of the table, clockwise, Dr. P. S. Henry, Dr. J. S. Forrest, Professor E. A. Owen, Dr. James Taylor, Professor W. E. Curtis, Dr. C. Sykes, Sir George Thomson, Sir John Cockcroft, Professor A. M. Tyndall, Dr. B. P. Dudding, Mr. E. R. Davis, Professor F. A. Vick, Dr. W. H. Taylor, Dr. M. R. Hopkins, Mr. H. P. Rooksby ; on the inside of the table, clockwise, Dr. H. R. Lang, Mr. R. G. Wood, Dr. K. A. G. Mendelssohn, Mr. O. W. Humphreys, Dr. H. Barrell, Mr. A. T. Pickles, Dr. J. M. A. Lenihan, Mr. N. Clarke.

of the Board and the Institute's permanent officers. It was engraved as follows :

> " Presented to Dr. Bernard P. Dudding on July 17, 1956, by past and present members of the Board and the permanent officers of The Institute of Physics to mark their personal regard for him on the completion of his ten year period of service as Honorary Secretary."

On the same occasion the President presented to Sir George Thomson a diploma of Honorary Fellowship of the Institute, to which grade Sir George had been elected at the Annual General Meeting held on the previous day.

Sir George Thomson (left) and Sir John Cockcroft.

Conference on Degree and Diploma courses in Applied Physics

Arrangements are almost completed for the conference on "Degree and Diploma courses in Applied Physics" that is to be held jointly by the Institute and the London and Home Counties Regional Advisory Council for Higher Technological Education. The conference will take place on November 15 and 16 at The Institution of Electrical Engineers. Among the speakers are Mr. O. W. Humphreys, Sir John Cockcroft, Mr. R. E. Burnett, Dr. John Thomson, Professor P. M. S. Blackett, Sir Francis Simon, Professor H. Lipson, Professor M. R. Gavin and Dr. J. E. Richardson.

An informal dinner will be held on November 15 at which Sir John Maud, formerly Permanent Secretary of the Ministry of Education, has promised to give an address.

The detailed program and form of application to attend the conference will shortly be available from the Deputy Secretary, to whom requests should be sent. A conference fee of one guinea will be charged to all attending.

"X-ray diffraction by Polycrystalline Materials"— One of "Fifty Beautiful British Books."

The Publishers' Association recently invited Sir Basil Blackwell to make his choice of fifty books to be included in the beautiful books section of the Frankfurt Book Fair which is being held this month. The arrangement for the display of the books at Frankfurt is being made by the British Council and the books are afterwards to be presented to the Council. Among the fifty chosen by Sir Basil is "*X-ray diffraction by Polycrystalline Materials*," edited by H. S. Peiser, H. P. Rooksby and A. J. C. Wilson and published by the Institute. The inclusion of this Institute publication is a much appreciated tribute to the excellence of the work of the individuals and firms who were responsible for its production.

Editorial Assistance Required

Members who are willing to assist with the preparation for the press of manuscripts accepted for publication in the Institute's scientific journals are invited to write to the Editor; previous experience of such work is desirable. The work would probably take only a few hours weekly and could be done at home. Remuneration would be fixed by agreement. Letters replying to this invitation should be addressed to Dr. H. R. Lang at the Institute, marked "Personal."

Abstractors Required

The Editor of *Science Abstracts* appeals for more members of the Institute to help in the work of abstracting the world's physical literature in *Physics Abstracts*. The success of such a journal depends upon the co-operation of numerous specialist physicists willing to read and to summarize articles on their own subjects in foreign languages as well as in English. By undertaking work of this kind, for which fees are paid, abstractors are enabled to obtain copies of papers on their own subjects, some of them proof copies of journals received in this country before the regular issues arrive. Offers are required for nearly all subjects but especially solid state physics and nuclear physics, and also for nearly all languages, especially German and Russian. Offers of assistance and any other inquiries should be sent to the Editor, *Science Abstracts*, The Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Nothing but the Truth ?

BY

F. W. G. GREENER, B.Sc., F.C.I.P.A., A.Inst.P.

DURING ARMY MANOEUVRES some years ago the field telephone became inoperable, and messages had to be transmitted, over one stage of their journey, by shouting from man to man along a mile-long line of men spaced 50 yards apart. The local headquarters was surprised, at the height of " battle," to receive a message from the front line reading " Send me three and fourpence, I am going to a dance." Only later did it turn out that the message as transmitted was " Send me reinforcements, I am going to advance."

Whether or not this story contains any element of truth, it serves to draw attention to one factor limiting the accuracy with which information can be passed between human beings.

It has lately become commonplace to complain of the lack of clarity and accuracy with which information is passed in writing or speed by persons of scientific qualifications or attainments. While some of that criticism can, no doubt, be justified, it may be of interest to consider briefly what defence can be offered in other cases. A few more or less obvious propositions may help to define the matters under consideration.

1. For precision in the transmission of an idea there must be a common mental outlook between the two persons concerned. It is, for example, obviously impossible to convey the idea of " red " or " blue " to a person blind from birth : or the idea of music to an individual born deaf. What is, perhaps, not quite so obvious, is that a *slight* difference in mental outlook between two persons may lead to a disproportionate distortion of an idea, transmitted by one person with complete clarity and accuracy from his point of view, when interpreted by the recipient in a manner which is completely accurate and precise from his point of view.

2. The means of transmitting ideas are incapable of absolute accuracy. It is sufficiently surprising that comparatively crude markings on paper, or sound-oscillations in air, can convey ideas as precisely as they do. It would be foolish to expect accuracy outside the physical limits of these means.

3. Simple statements can only express simple ideas ; more complicated statements are liable to ambiguity, and/or distortion in interpretation by a recipient. Nature and life are not simple, and there is a distinct danger that to select a simple statement in order to achieve clarity of expression is to transmit an incomplete or distorted idea.

There is, of course, nothing new in this problem of the accurate transmission of ideas by words, whether written or spoken. It is, in fact, the basic problem facing a lawyer. The law is set out in words and phrases selected by highly skilled men, whether judges giving common law judgements, or Parliamentary draftsmen setting out the intentions of Parliament in Statute Law ; and the Law attempts to lay down with clarity and exactitude, what is required of, and what is forbidden to, persons to whom it applies. The Courts, assisted by the legal profession, are thereafter continuously engaged in determining the precise meaning and limits of the words and phrases employed.

This position does not arise from perversity or self interest on the part of Parliament, the Courts or the lawyers, but from limitations to the effectiveness of words to convey ideas accurately. The complexity of wording, and the so-called " jargon " employed in law is not selected, as some laymen appear to believe, in order to confuse the issue, but because experience has shown that any other wording or mode of expression would be even less precise, and even more difficult

to understand or construe, than that adopted. Anyone seeking a little mental exercise in this field can readily find suitable material in the Rules of the Institute, especially those relating to professional conduct, which he will find capable of more than one interpretation.

A few examples, both in everyday speech, and in law, may be mentioned.

One of the most difficult words in wide use (and probably used more widely by physicists than most other people) is the word " equal." What does it mean ? Consider, for example, phrases such as " Equal pay for equal work," or " All men are born equal." The word is clearly not synonymous with " the same " or " identical " because if so the above statements would be obviously untrue : but in what other sense can two different babies, or two different performances of work, or receipts of payment, be " equal " ? Is its meaning any clearer in scientific parlance, e.g. " action and reaction are equal and opposite " ? One might expect that in mathematical statements precision could be relied upon, but the same difficulty arises in the simplest formulae, e.g. :

$$(a^2—b^2) = (a—b)\ (a+b).$$

It is quite clear that the same word has different meanings in the different examples quoted, but that these various expressions do, in fact, convey ideas of some kind between persons who, *on account of a common mental outlook*, believe that they have a common understanding of the word " equal." It is far from clear, however, that the word does, in fact, mean exactly the same to one person as to another, when exchanging an idea : nor is it quite clear that the word has a *precise* meaning to either party. The point of this example is that while a person using the word " equal " in conveying an idea may be open to some blame for lack of clarity and precision in his statement, part of the trouble arises from inherent inaccuracy in the word itself and some further trouble may arise from a different mental outlook of the recipient. Careful analysis will show that many ordinary words and phrases in use suffer from the same inherent defect, and the most innocent looking phrases, including many frequently and commonly used without question, can be extremely misleading or inaccurate.

Examples of innocent words and phraseology which have been held to lack precision or clarity are to be found in Patent Law. A patent specification is intended to describe an invention clearly and concisely, and must terminate with one or more claims setting out in exact language the novel feature or combination of features defining a construction which third parties may not employ without the permission of the patentee. If the claim or claims is/are unclear or ambiguous it will be impossible for a reader of the specification to be certain whether or not any particular action by him is, or would be, inside or outside the scope of the claim(s), and in those circumstances a Court of Law would decide the patent to be invalid and unenforceable. The patentee would lose his monopoly. On the other hand the claim must be expressed in terms as wide as possible, since if it is of narrow scope a competitor might be able to adopt most of the advantages of the invention without infringing the claim. The preparation of a patent claim therefore demands the greatest care in selecting words and phrases which are not only of wide meaning, but of precise significance. The simplest words have to be selected and scrutinized with care. Consider the word " bent." Suppose that in defining an invention reference is made in a claim to . . . " a pipe supported by a bracket bent at right angles to a wall, etc." In interpreting this claim it can be argued that the bracket can only be " bent " from a strip initially flat, so that anyone employing a bracket cast initially as an angle piece would not be infringing this claim. Even if that interpretation is not upheld it can still be argued that, because the phrase referred to is open to more than one interpretation it is ambiguous, and therefore invalid.

In 1934 a patent was granted covering a process for removing dispersed matter from aqueous dispersions, and was intended to deal with suspensions of clay, slate, flue-dust

and the like, encountered in industrial operations. One step in the process claimed was to add to the dispersion a gel obtained by mixing an amylaceous material with a neutral hydrated metallic salt and subjecting this mixture to heat and agitation. During an infringement action, in which much expert evidence was offered, it became clear (and was so held by the Court) that no classification of salts was known to scientists, or defined in the specification, from which one could ascertain precisely what was a " neutral " salt. This innocent word " neutral " turned out to be unclear and ambiguous, and the claim was therefore held invalid, and the infringement action failed.

In another patent infringement action, a claim in dispute related to an electric generator for a cycle comprising a multipolar, annular, permanent magnet, and a wound multipolar armature. The Court held that the expression " multipolar " was not sufficiently defined to show precisely what was meant, and since it was ambiguous the claim was invalid.

Another term which has been under fire for ambiguity or lack of precision in a patent infringement action was " capillary tube."

It will be seen therefore that simple words and phrases in common use are not necessarily as precise or free from ambiguity as we should like to believe.

Nor, when simple and clear words are used, is it certain that they mean the same thing to the parties concerned. *A* entered into a contract with *B* for the purchase of a cargo of wheat due shortly to leave Bombay in the S.S. " *Peerless*." When the cargo had not arrived on the date expected by *A*, *A* repudiated the contract and was sued by *B*. It turned out that two ships each named S.S. " *Peerless* " were due to sail from Bombay with cargoes of wheat shortly after *A* and *B* completed negotiations. One, which *A* had had in mind, was due to sail early in October whereas the other, which *B* had had in mind, was not due to sail until the end of November.

These facts might, perhaps, advantageously be borne in mind when we feel that a communication (whether on a scientific or any other matter) is open to criticism. Remembering that accurate transmission of an idea depends upon both the communicator and the recipient, we might before criticising, perhaps first make sure that the apparent confusion has not, at least in part, originated in our own minds. Even the most well-founded criticisms are not entirely without rebuttal. For example, omission of a verb from a sentence is generally regarded as inexcusable ; yet students of Latin (in which language great advances in law and Government were clearly enunciated) will remember many phrases whereby quite precise ideas were conveyed without the use of a verb, e.g. " *De mortuis nil nisi bonum.*"

Pursuing these considerations to a logical conclusion seems to suggest that the main function of words and symbols, written or spoken, is not, as generally held, to convey (or in some cases to conceal) ideas, but is rather to stimulate, modulate or associate ideas already implanted in the mind of the recipient. If this is true it seems to follow that criticism of the written or spoken word because it is allegedly unclear or misleading, necessarily implies some limitations upon the mental equipment of the person offering the criticism. It may, therefore, be dangerous to allow any such criticism to influence one's mind, taste or judgement when written or spoken words are under discussion.

With these considerations in mind we might perhaps sympathize with the Frenchman, who, having a limited knowledge of English, attended the Institute conference in Glasgow some years ago. He had travelled by train to Glasgow from London, with a friend who had purchased single tickets for both, and the Frenchman was intending to travel back to London alone by train. Considerable difficulty arose at the Glasgow booking office, when he deposited the exact fare for a single journey, but insisted that he wanted a return ticket to London : and who can say he was wrong ?

Forthcoming Institute Meetings

Sept. 19–21 Stress Analysis Group — At the College of Aeronautics, Cranfield

Joint Conference with the Royal Aeronautical Society

(Details and forms of application may be obtained from the Deputy Secretary)

Sept. 26–27 Liverpool and North Wales Branch

At the University College of North Wales, Bangor

Symposium on

"*Magnetic Resonance*"

Further particulars of the symposium may be obtained from Professor E. R. Andrews, F.Inst.P., Physics Department, University College of North Wales, Bangor, Caernarvonshire. Accommodation will be available for a limited number in the Hall of Residence for Men Students.

Sept. 28–29 Electronics Group — At the University of Reading

Symposium on

"*Thin Films*"

(Details may be obtained from the Deputy Secretary)

Oct. 9 Scottish Branch — 7.15 p.m.

In the Natural Philosophy Department, University of Glasgow

Chairman's address :

"*Physics and Physic*"

DR. J. M. A. LENIHAN, F.INST.P.

(Regional Physicist, Western Regional Hospital Board)

Oct. 10 Education Group — At the Institute's House, 5.30 p.m.

"*Technical Education — Problems of Quality and Quantity*"

DR. P. F. R. VENABLES

(College of Technology, Birmingham)

Oct. 12 Manchester and District Branch — 6.45 p.m.

In the Bragg Building, University of Manchester

"*Nuclear Magnetic Resonance*"

PROFESSOR E. G. COX, F.INST.P., F.R.S.

(University of Leeds)

Oct. 12 South Wales Branch At the University College, Cardiff, 5.15 p.m.

"*A Physicist's Approach to Crystal Structure Determination*"

PROFESSOR H. LIPSON, F.INST.P.
(College of Technology, Manchester)

Oct. 12 Liverpool and North Wales Branch At the University of Liverpool, 7.00 p.m.

"*Nuclear Magnetic Resonance*"

PROFESSOR E. R. ANDREW, F.INST.P.
(University College of North Wales)

Oct. 15 Scottish Branch At the University of Edinburgh, 7.15 p.m.

Chairman's address :
"*Physics and Physic*"

DR. J. M. A. LENIHAN, F.INST.P.
(Physicist, Western Regional Hospital Board)

Oct. 16 Midland Branch At Regent House, Birmingham, 7.00 p.m.

"*The Physics of Clothing*"

MR. W. H. REES, F.INST.P.
(British Cotton Industry Research Association, Manchester)

Oct. 16 Electronics Group At the Institute's House, 5.30 p.m.

"*High Vacua*"

MR. M. E. HAINE, F.INST.P.
(Associated Electrical Industries Ltd., Research Laboratory, Aldermaston)

The Graduateship Examination, 1956

THE INSTITUTE'S Graduateship Examination was held on June 11-15. Written papers were taken in London (the Institute's House), Birmingham (College of Technology), Salford (Royal Technical College), Paisley (Technical College) and a practical examination was held at The Polytechnic, Regent Street.

Although the number of candidates accepted for the examination was originally slightly more than for last year, there was a heavy withdrawal. Forty-five candidates took the papers (other than the General paper) and of these candidates, only seven satisfied the Examiners, the successful candidates being :—

J. L. E. Baldwin - London
F. G. Brightman - Holmrook, Cumberland
J. A. Cheatham - Birmingham
D. P. Donegan - Salisbury
A. J. Higgins - Wiggin
N. W. L. Lee - London
G. E. Morris - London

All the candidates already held a qualification which entitled them to substantial exemption from the Graduateship Examination. Holders of the London General degree

at pass standard and of similar degrees are required to take two written papers and, at the discretion of the Examiners, a practical examination. Holders of the Higher National Certificate in Applied Physics are given exemption depending upon their performance in the Certificate examination, the maximum exemption being from all except two written papers. An analysis of the results according to the academic status of the candidates is :—

	Candidates	*Passed*	*Failed*
Holders of degrees	17	5	12*
Holders of the Higher National Certificate in Applied Physics	28	2	26†
	45	7	38

* 8 failed in both papers taken
† 12 failed in all papers taken.

Seven candidates took the General paper in order to comply with the Institute's requirement of evidence of general education and two candidates satisfied the Examiner.

The results in each paper were :—

	No. of Candidates	*Passes*
Physics I (General Physics and Acoustics) ...	27	12
Physics II (Heat and Optics)	23	10
Physics III (Electricity and Magnetism) ...	4	1
Mathematics I	1	—
Mathematics II ...	1	—
More Advanced Physics	17	6
Electronics	13	5
Nuclear Instruments and Measurements ...	1	—
Statistics	3	2
X-rays	4	1
Practical examination ...	4	3
General Paper	7	2

The papers set in the examination are reproduced in this issue of the *Bulletin*.

COMMENTS OF THE EXAMINERS

PHYSICS I—Professor J. G. Wilson

There were twenty-seven candidates, and it is encouraging that no candidate attempted fewer than four questions. However, almost all scripts brought out a sharp difference between what has been learnt, and which can therefore in favourable conditions be reproduced, and anything demanding even slight originality of treatment. This feature is the most serious shortcoming of almost all candidates, but it is also pre-eminently that upon which the existing qualifications of most candidates are felt to be deficient. Examples are noted below.

Apart from a few dreadful examples, the standard of composition was a little better than last year, but the use by one candidate of "in vicinity of propagation" when he meant "near the source" illustrates an unfortunate tendency to use long words with a technical flavour instead of simple English, even when the meaning of the long words is in doubt.

Q. 1. Many candidates could not write about a "suitable compound pendulum" without first wasting a lot of time writing about adjustable compound pendulums and experiments they had done with them. They did not select.

The rider showed the difficulty experienced by almost all candidates in setting down a simple numerical problem with elegance.

Q. 2. Candidates found it difficult to think from what they had done themselves, however crude this might have been, to a procedure aimed at a precision measurement.

Q. 3. This question, like a similar one a year ago, yielded incredibly poor answers.

Q. 4. Answers were disappointing ; several candidates almost certainly had the ideas to make a good answer but could not bring them together properly.

Q. 5. Almost every candidate attempting this question knew something relevant, but the distinction between a few who marshalled their material logically and those who wrote at random was striking. There was much uncertainty about the pressure ranges of the various gauges.

Q. 6. This was not a popular question and

proved much too difficult for those who attempted it.

Q. 7. The rider of this question tested the ability of candidates to describe a simple physical situation in analytical form. Most candidates had no idea at all how to do this.

Q. 8. This question produced the outstanding answer of the whole paper in which the essential points were set out with notable clarity and economy of words. Most of the other answers were confused and incomplete.

Q. 9. In this question most of those attempting it had an adequate understanding of the matter, but few gave any attention to effective presentation.

PHYSICS II—Professor H. Lipson

The standard, on the whole, was low. The most disappointing feature was the general dependence upon facts and bookwork and the almost complete absence of constructive ideas. At this level of examination only the introduction of the candidates' own ideas can allow proper discrimination between the good and the poor. The following are the examiner's main comments on the answers to the individual questions.

Q. 1. The basic principles of refrigeration seemed to be reasonably well known, although several candidates confused the Joule-Thomson effect with ordinary adiabatic-expansion cooling. The more intimate details, such as the reasons for particular working fluids, were, however, lacking.

Q. 2. Many answers were far too elementary ; candidates at this level should know that the specific heat of a body at about 500° cannot be determined by the method of mixtures. Moreover, the question concerned the *variation* of specific heat with temperature. At high temperatures, cooling is important and cannot be dismissed casually.

Q. 3. No candidate attempted this question.

Q. 4. Most candidates could say something about entropy, although few seemed to appreciate its significance. No one mentioned the entropy contribution to free energy, which normally decides the condition for stability of a phase.

Q. 5. The change in speed when a molecule rebounds from a moving surface was generally appreciated, but no candidate envisaged other than normal incidence or was able to take the analysis to the stage of calculating the *frequency* of collisions and thence the total change of energy in unit time.

Q. 6. The distinction between Fraunhofer and Fresnel diffraction was well stated. But the problem of calculating the Fraunhofer diffraction pattern of three slits was too much for any candidate. Some candidates could produce an answer for N slits, but could not substitute N = 3 !

Q. 7. The phenomenon of the passage of light through a birefringent crystal was treated at too low a level. No candidate dealt with the passage of convergent light through a crystal, although the polarizing microscope is used largely in this way.

Q. 8. There was much factual statement about numerical apertures and f-numbers. No candidate dealt adequately with the effect of f-number on depth of focus and of field, although the effect of intensity of the image was well understood.

Q. 9. The treatment of spherical aberration was very poor. Candidates knew what it was, but did not appreciate the part played by variation of angle of incidence. Some simple calculations with prisms would have helped considerably.

PHYSICS III—Professor H. Lipson

Only four candidates attempted this paper, and it is therefore hardly possible to generalize about the answers. There was evidence, however, that candidates were attempting to learn formulae rather than to understand principles. One candidate even quoted (correctly) the expression for the orbital energy of an electron without even mentioning quantum theory !

With so few candidates not all the questions were attempted. The following notes concern only those questions which were attempted by more than one candidate.

Q. 2. There was little evidence of quantitative knowledge of magnetic fields. Still more surprisingly, in view of the numerous articles on the subject, little seemed to be

known of the use of magnetic methods in prospecting.

Q. 4. The question on Kirchhoff's laws, although elementary, was poorly done. No use was made of symmetry in attempting to find the resistance of a cubic network of resistors.

Q. 6. The basic principles of the use of complex quantities in alternating-current problems did not seem to be generally understood. Some candidates were able to set up the equations, but then quoted the solutions.

Q. 9. A great deal, much of it nonsense, was written about X-rays. Candidates should know that they cannot expect to satisfy examiners with vague and physically meaningless statements. (For example "Radiations are set up externally to the tube which consists of a motion of particles.")

APPLIED PHYSICS—Mr. A. E. De Barr

In comments of this kind it is almost inevitable that attention should be concentrated on the deficiencies of the candidates. It is only fair to point out, however, that this year there was one really good paper and, amongst many indifferent efforts, at least one good answer to most questions. An unsatisfactory feature of the results is that the average mark for the numerical questions, even though these were marked rather more generously than the others, was significantly less than that for the descriptive questions. Only two candidates attempted more than two numerical questions.

ELECTRONICS—Mr. A. E. De Barr

It was heartening to find one or two candidates who really seemed to understand equivalent circuits and, more important, could use them to obtain numerical answers.

Q. 1. Only three candidates attempted this question. They knew some of the semiconductor jargon, but quite clearly had no idea at all of the physical mechanisms involved in rectification or transistor action.

Q. 2. Most candidates seemed unable to attempt any comparison of the performance of a photomultiplier with that of an ordinary photoelectric cell followed by an amplifier.

Q. 3. This was the most popular question and was answered by ten candidates, but only one sketched the distribution of potential between anode and cathode of a pentode!

Q. 4. In view of the current popularity of the so-called long-tailed pair circuit it was rather surprising that only one candidate came anywhere near to a satisfactory explanation of its behaviour. Those who had clearly not come across the circuit before made lamentable efforts to analyse what is, after all, a very simple type of circuit.

Q. 5. Most of the equipment suggested would have worked satisfactorily—although one candidate suggested the use of a gamma-ray source for measuring the thickness of paper!—even if it would have been rather impracticable.

Q. 6. There were five different answers to this question, and all were wrong. Nearly every answer contained the phrase "it is assumed that the field between anode and cathode is uniform!" Worse still, most candidates then calculated the velocity of the electron at the anode—and calculated the transit time on the basis that the electron possessed this velocity all the way from cathode to anode! Only one candidate got so far as to write $V \propto d^{4/3}$ — and then crossed this out and made the same mistake as the rest!

Q. 7. Only one candidate appreciated that he should draw a load line for alternating currents only—all the others drew load lines for direct coupled loads. There were no satisfactory numerical answers.

Q. 8. Some candidates knew how to apply the equivalent circuit idea and get the correct answer. The rest just floundered in a maze of symbols.

Q. 9. There were no correct answers. Candidates usually got as far as calculating the change of voltage at the grid of V_1, but then omitted to realize that the current through V_1 flows through the (unknown) load as well as through V_1.

X-RAYS—Mr. A. E. De Barr

Q. 1. This question was answered by all the candidates but, although their accounts of the changes in the nature of the radiation

were generally good, the connection with the atomic structure of the anode material did not appear to be understood. The existence of, for instance, more than one K line, or the simultaneous appearance of all the K lines as the voltage is increased, were not explained. Candidates also assumed that the tube was supplied with direct current ; there was no mention of the effects with an alternating or rectified voltage.

Q. 2. It was gratifying to find that most candidates did have some idea of the efficiency of production of X-rays. Most explained that anodes were usually water-cooled and mentioned the advantage of using a material of high thermal conductivity, but did not discuss how best to make use of a flow of cooling water to remove the heat dissipated at the anode. In answer to (*b*) line focus tubes and inclined target faces were mentioned but no description of focusing systems was given.

Q. 4. The candidates who attempted this question all referred to the use of charts to determine the appropriate voltage and current, and gave no explanation of the basis on which such charts are constructed. None of the answers to (*b*) referred to the use of counters to monitor the package : all assumed that fluoroscopic examination was necessary.

Q. 6. With one exception candidates had no idea of the relation between the saturation current in an ionization chamber and the X-ray dosage rate, or of that between the energy in the X-ray beam, the energy absorbed and the dosage rate.

Q. 9. Candidates seemed to be unaware of the simple relation between the values of $\sin^2\theta$ for the different lines—most tried to identify the lines using sin θ values. The number of atoms in the unit cell was not even mentioned in some answers.

PRACTICAL PHYSICS—Mr. A. E. De Barr and Mr. J. Yarwood

Three features are worthy of comment.

Q. 1. It is remarkable that candidates—who may even have offered More Advanced Physics in the written examination—should be ignorant of definitions and formulae that a first-year undergraduate should know.

Q. 2. As in previous years candidates appeared not to have seen apparatus such as commercial potentiometers, Geiger counters and scaling equipment or even vacuum pumps. They are not expected necessarily to be familiar with the use of such items as the last two mentioned but should have seen and used them before.

Q. 3. Candidates do not appreciate the importance of writing an adequate account of their experiment. They do not realize that, without a description of the measuring procedure adopted, their results may have very little meaning. Even where details are given in the written account, they all too often refer to domestic items such as lighting the gas or filling the calorimeter with water. Important features of measuring procedure—such as how the internal diameter of a rubber tube was measured—are rarely described.

STATISTICS—Mr. E. D. van Rest

From the way the questions were tackled I feel no doubt that the questions, with the exception of one, were within the candidates' fields of study. They showed some acquaintance, even if slight, with each one attempted. The exception was question 5 dealing with the compounding of errors.

None of the candidates showed a thorough understanding of statistical principles. Words were used loosely and statistical terms sometimes wrongly. Formulae written down to introduce a calculation were often slightly wrong ; the absence of an index or the placing of an n in the denominator instead of the numerator showed that memories rather than principles were being relied on. In any case of extended calculation the answer was usually wrong because of a single slip, showing that probably no check had been made.

MORE ADVANCED PHYSICS—Professor J. G. Wilson

There were seventeen candidates, of whom one produced a quite outstanding script. Apart from this man's work, however, the standard was disturbingly low, and almost every question produced some grotesque

mis-statement as, for example, when the neutron was said to have no mass but to be charged. More generally, many of these candidates showed little facility for handling even what they knew to meet anything but a direct question.

Q. 1. The weakness of answers to this question was surprising. The term " free neutron " did not seem to be known to many.

Q. 2. The answers here were poor. The accepted general method was known, but the features which make it accurate were not.

Q. 3. Some effects which lead to line broadening were known to most of those attempting this question, but there was the temptation to expand irrelevantly on what was known, and nothing in the nature of a balanced answer was submitted.

Q. 4. This question, like the preceding one, lead to disappointing answers. Most candidates knew quite a lot about magnetism, but this was usually presented piecemeal, and not all of it was relevant to metals. There was no evidence of any preliminary scheme upon which an essay-type answer, such as that demanded here, ought to be built.

Q. 5. This question proved far too hard for most of those who attempted it. The Compton effect seems generally known in the past, and not as an effect of current application.

Q. 6. Candidates generally were more at home on this question than on any other, and there were some fairly good answers. Thermionic emission was well treated, and so, on the whole, was field emission. Photo-electric emission was not so well done, and provided opportunity for irrelevancies.

Q. 7. Except for those of candidates who came to this question short of time, the answers were of fair quality, although not very up to date. A few candidates had heard of the anti-proton.

GENERAL PAPER—Mr. N. Clarke

The standard was perhaps slightly better than in previous years.

Q. 1. As usual, the précis question was fairly well answered but none of the candidates could give adequate—or even plausible—meanings for all the words given in the second part of the question. The following are some of the definitions given : *valedictory*—ever changing ; *cadence*—of high morality ; *Augustan*—sweeping or exaggerated, from the teachings of St. Augustan (*sic*) ; *cadence* (spelt " candence ")—importance ; *cadence* —analogous to the " Amen " as sung after hymns, etc. ; *valedictory*—means a permission dictated sometimes by time ; (unconsciously apt) *clichés*—a few well chosen words.

Q. 2. The essays, three on " London," two on " Teddy Boys " and two on " Nuclear Physics," were poor.

Q. 3. All four candidates who attempted the first alternative of question 3 appear to enjoy life in the present day. None had any regret that he had not lived in a past age.

The three candidates who chose the second alternative had nothing to say ; none of them betrayed the slightest acquaintance with ethics, philosophy, religion or literature.

Q. 4. Surprisingly, this question, which ought to have been very easy for any aspiring physicist, was attempted by only four candidates. One of them wrote with some knowledge of the work of Sir Lawrence Bragg and another gave a few facts about Sir John Cockcroft's career, but five of the candidates apparently knew nothing about any of the four distinguished physicists referred to. The following is the answer, in its entirety and original spelling, of one candidate (over 30 years of age) who wrote on Lord Cherwell : " A great physicist was placed in charge of armorment research for the Ministry of Supply and after hostilties had ceased he resigned and later to over the supervision of Atomic Research at Aldermastern." Presumably this candidate thought he knew less about the other three physicists.

Q. 5. Six candidates chose the first alternative and one the second. The answers were better than might have been expected and one of them was quite good.

Papers set in the Graduateship Examination, 1956

PURE PHYSICS I — GENERAL PHYSICS AND ACOUSTICS

Examiner : PROFESSOR J. G. WILSON, M.A., PH.D., F.INST.P.

MONDAY, 11th June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions, at least* THREE *from Section A and at least* ONE *from Section B*)

SECTION A

1. Discuss the difficulties in determining g, the acceleration due to gravity, by means of a simple pendulum, and show to what extent these are overcome by the use of a suitable compound pendulum.

The distance of the moon is about 60 times the radius of the earth, and its mass about 1/80th that of the earth. What maximum variation in g (at the surface of the earth) will arise from the relative motion of the earth and moon ?

2. You are required to carry out an experiment to make an accurate determination of the viscosity of water by observations of flow through a capillary tube. Discuss the precautions you would take and the measuring procedures you would adopt, directing attention to those features which would probably limit the overall accuracy of your determination.

3. Observations of the activity of a weak radioactive source are made by means of a counting method in which counting rates are measured, with and without the source, as follows :—

Time interval (min.)		*Number of counts recorded*	
		With source	*Without source*
30	...	—	472
30	...	527	—
180	...	—	2734
180	...	3175	—

Determine the counting rate attributable to the source, and its statistical uncertainty. For approximately how long would counting have to be carried out in order to determine this rate to within 1% ?

4. " Kinematic design, as that term is frequently used, implies a design whereby the various links of each element forming an instrument are constrained by the theoretically minimum number of point contacts, given the degree of constraint required.

The claims for such a design are so frequently overstated that it will be well to consider its very real merits, and its limitations." (T. N. Whitehead, *The Design of Instruments and Accurate Mechanism.*)

Discuss kinematic design along the lines proposed in the second paragraph.

5. Give a short account of the principle and design of important types of vacuum gauge explaining the features which fit the various instruments for different pressure ranges.

6. Two simple pendulums are coupled through a yielding support, and one, of variable length, is used to drive the other.

Explain what will be observed when in successive experiments the length of this pendulum is gradually decreased from a value greater than the length of the driven pendulum to a value shorter than this length.

To what extent would what you observe depend upon the nature of the bob of the driven pendulum ?

SECTION B

7. What is meant by the Doppler effect ?

The whistle (frequency 600 c/s) of an engine travelling at 90 ft./s is heard by an observer standing 10 yards from the railway track. Obtain an expression for the frequency of the note which he hears. How would you expect the intensity of the sound to change ? (Assume an appropriate value for the velocity of sound in air.)

8. When a sound is heard, one is usually able to tell the direction from which it has come. Discuss the physical principles upon which you think that this judgement may be based.

9. Give an account of sound production in the main categories of musical instrument. In a stringed instrument what considerations determine the choice of point at which a string is struck or bowed ?

PURE PHYSICS II — HEAT AND OPTICS

Examiner : PROFESSOR H. LIPSON, M.A., D.Sc., F.INST.P.

MONDAY, 11th June—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions, at least* TWO *from each section*)

SECTION A

1. Discuss the principles involved in refrigeration.

Describe the construction and mode of operation of one form of domestic refrigerator.

2. What methods would you use to determine accurately the variation with temperature of the specific heat of an alloy in the range 0–500°C. ?

Explain what results would be expected with an alloy that undergoes a phase change.

3. Discuss the application of the phase rule to the equilibrium diagrams of alloy systems.

Give examples of the different types of diagram that can occur for binary systems.

4. What is meant by (*a*) the entropy, (*b*) the internal energy of a system ? Discuss the importance of entropy as a fundamental thermodynamic concept and as a measure of the degree of disorder of a system.

Explain why the sequence of solid, liquid and gaseous states of an element occurs always with increasing temperature.

5. Explain how the concept of equipartition of energy leads to Avogadro's principle that equal volumes of gases at the same pressure and temperature contain the same number of molecules.

A perfect gas is contained in a sphere which is expanding. By considering the change in energy when a molecule rebounds from the moving surface, show that the temperature falls as the volume increases, and deduce a relationship between the temperature and the volume.

SECTION B

6. Explain the distinction between Fraunhofer and Fresnel diffraction patterns.

Derive the form of the intensity distribution in the Fraunhofer diffraction pattern of three similar parallel equidistant slits whose breadths are negligible compared with the distances

between them. Explain how the result is modified as the number of slits increases, and thence discuss the dependence of the resolving power of a diffraction grating on the number of elements it contains.

7. Describe the main phenomena involved when light passes through a birefringent crystal. Explain the use of the polarizing microscope to examine such a crystal, and describe some typical results.

8. Explain what is meant by (*a*) the numerical aperture of a microscope objective, (*b*) the *f*-number of a camera lens. Discuss the importance of these quantities in the performance of these instruments.

9. What is meant by spherical aberration in image formation by a lens ? Discuss the statement that spherical aberration is minimized if the deviations produced at the separate surfaces are equal. Thence explain why a planoconvex lens produces less spherical aberration than a symmetrical lens of the same power when used to bring parallel light to a focus.

PURE PHYSICS III — ELECTRICITY AND MAGNETISM

Examiner : PROFESSOR H. LIPSON, M.A., D.SC., F.INST.P.

THURSDAY, 14th June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions, not less than* TWO *from each section*)

SECTION A

1. Derive an expression for the force per unit area on a surface charged electrically with a surface density σ. Thence derive an expression for the force of attraction between the plates of a parallel-plate condenser. Explain how the result can be used in designing an instrument for the absolute measurement of potential difference.

Suggest approximate dimensions for an instrument suitable for measuring potential differences of the order of 1 kV. (1 e.s.u. = 300 volts.)

2. Describe the general features of the Earth's magnetic field and show that they are similar to those of the field that would be produced by a magnet at the centre of the Earth.

Discuss the methods available for accurate measurement of the Earth's field and explain how the methods have been used in prospecting for minerals.

3. Discuss the analogy between the electric circuit and the magnetic circuit.

An iron rod 50 cm long and 2 sq. cm in cross section is bent so that the ends are separated by a gap of 1 mm. On it are wound 500 turns of wire through which is passed a current of 1 amp. If the permeability of the iron is 900, determine the strength of the magnetic field in the gap.

4. State the laws governing the passage of electric current through a network of conductors containing sources of e.m.f.

Two batteries of e.m.f. 7 V and 8 V and of internal resistance 0·4 Ω and 0·2 Ω respectively are connected in parallel and used to pass current through a 5 Ω resistance. How much current is contributed by each battery ?

Find the resistance across two opposite corners of a network of twelve 1 Ω resistances connected together to form the edges of a cube.

SECTION B

5. Explain the importance in the distribution of electricity of (*a*) the three-phase system, (*b*) high-voltage supply lines.

Loads of 100, 120 and 150 kW are taken by the three phases of a 400 V system. If the frequency is 50 c/s derive an expression for the current in the return lead.

6. Discuss the use of complex quantities in solving alternating-current problems.

Investigate the behaviour of a circuit consisting of a condenser of capacity C in parallel with a coil of self inductance L and resistance R when an alternating potential difference of varying frequency is applied across it. Give one practical use of the circuit.

7. Describe in detail, giving the theory of the instruments used, a method for measuring the ratio between the unit quantities of electricity in the electrostatic and electromagnetic systems. What fundamental significance has the result ?

8. Describe the double-beam cathode-ray tube.

How would you use (*a*) a cathode-ray tube to trace a B-H curve for an iron specimen, (*b*) a double-beam cathode-ray tube to demonstrate the variation in the phase difference between the applied voltage and the current in a series tuned a.c. circuit containing capacitance and inductance, as the frequency of the applied voltage is altered ?

9. How are X-rays produced ? Explain the difference between the origins of " white " X-rays and characteristic X-rays. Mention specifically the occurrence of the minimum wavelength in the white spectrum, and the occurrence of certain faint extra lines in the characteristic spectrum.

MORE ADVANCED PHYSICS

Examiner : PROFESSOR J. G. WILSON, M.A., PH.D., F.INST.P.

TUESDAY, 12th June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions*)

The required numerical information is given at the end of the paper

1. State the grounds upon which it was expected that the neutron would prove to be unstable. Describe an experiment in which the decay of free neutrons has been observed, and indicate what features of the decay process have been studied.

2. Outline the sequence of observations upon which an accurate determination of Avogadro's Number, the number of molecules in one gram molecule, may be based.

3. Discuss the factors which determine the breadth of spectral lines in emission, and explain the conditions under which narrow lines may be obtained.

State the physical considerations which set the ultimate limit to the narrowness of lines.

4. Give a general survey of the magnetic properties of metals.

5. What is the Compton effect ? Explain the meaning of the statement that the cross-section for Compton scattering of 0·5 MeV gamma rays is

$$0{\cdot}43\,\frac{8\pi}{3}\left(\frac{e^2}{mc^2}\right)^2 = 2{\cdot}8\times10^{-25}\ \text{cm}^2.$$

What is the significance of $\frac{8\pi}{3}\left(\frac{e^2}{mc^2}\right)^2$?

In what thickness of carbon of density 2·5 g.cm^{-3} will 1% of the energy in a beam of this radiation be scattered. (Assume no other absorption or scattering mechanism operates.)

6. Describe a suitable model by means of which the emission of electrons from a metal surface may be described. State the condition under which thermionic emission, field emission and photoelectric emission will take place, and draw attention to common features and to differences in the three processes.

7. Write a short account of the developments which have taken place over the last twenty-five years in the methods used to accelerate protons to great energy.

Discuss shortly the reasons which have during this period made ever greater proton energies desirable.

Avogadro's Number = $6{\cdot}02 \times 10^{23}$.

GENERAL PAPER

Examiner : N. CLARKE, B.Sc., F.INST.P.

TUESDAY, 12th June—9.30 a.m. to 12.30 p.m.

(*Answer* ALL *the questions*)

1. (*a*) Give the substance of the following passage in your own words :

" An easy way to study the ups-and-downs of language and the different tastes of different generations in the use of words is to take one's gentler exercise in churches and churchyards, which are indeed the marble-index of a nation's mind voyaging in strange seas of valedictory emotion. This is a pastime open to all and one leading to serene and not altogether melancholy places.

" The church and its tombs are a chronicle of style and state of mind. As such they may be depressing because they reveal, at least during the last hundred years, a steady decline of taste in material, in sentiment, in diction, and in lettering. The oldest stones have a native modesty : their grey simplicity emerges without fuss : they seem to grow as naturally as the daises in the grass beside them. Even when fresh-cut they cannot have been out of place or flashily demonstrative, as are the sepulchres of alien marble which came into a later vogue. The words which they carry have a quiet dignity, and so has the lettering of these sincere and tranquil tributes. Men in those days were allowed to die : death need not be disguised with larger words.

" True, the eighteenth century had its pomps; it would put into an English village the amplitude of a Roman gesture and bid farewell to a Georgian Squire with an Augustan flourish. But there was style in the gesture, and, after all, our culture came very largely by way of Rome. The lover of words will forgive the pleasing classical rotundity and even delight in the fine formality of a dismissive phrase. Recently in a church of the Shakespeare country, to which I was the more attracted because so many of its dead were called by the name of Lively, I found a tablet upon the wall in honour of a young Georgian doctor's skill. By his art and science, it said, ' He prolonged the lives of others to lament his own dissolution.' The compliment may or may not be just ; the phrasing is certainly perfect. . . . . .

" . . . . . During the eighteenth century, according to my churchyard observations, people were allowed, quite simply, to die. Towards the end of that period they begin to 'depart this life.' That is a fuller term, but there is no evasion about it. All this time the valedictory compliments paid to these departed have a classical dignity on the more august sepulchres and a native good sense on the humbler stones. But about the year 1830 everything goes. It has often astonished me how sudden and all-inclusive was the collapse of taste. In a churchyard you notice no gradual decay, but a complete break.

" The craft of Journalism, like that of epitaphy, employed at that period a sounding vocabulary and a great sense of cadence. There were space and leisure for the ample phrase and this magniloquence was to be discovered as much in a local sheet as in one of the more august London journals. In a bar-parlour in a remote Derbyshire dale I once noticed on the wall a cutting from a local paper. It was an obituary notice, written in the early nineteenth century,

about a gamekeeper who had become a centenarian and had executed some high feats of agility and endurance even when he was reaching three figures. It was written of his habits—I must quote from memory :

> Until the age of sixty he consumed but one gallon of malt liquor a day : but later he began to drink plentiful, which he found agreeable to his constitution and an abiding comfort to himself.

" Such prose employs no rare words, but it patterns the familiar terms to a noble surge of sound. The modern form of farewell to such a veteran of the chase and tankard would probably be some mean string of clichés, far less candid and without the sap of feeling or the dignity of phrase."

IVOR BROWN
(*A Word in Your Ear*)

(*b*) Give the meaning of the following words in the context of the above passage : valedictory ; Georgian ; Augustan ; rotundity ; cadence ; magniloquence ; clichés.

2. Write an essay on one of the following subjects :

London
Cricket
The Duke of Edinburgh
Nuclear Power
" Teddy Boys."

3. EITHER (*a*) Is there any other period of time at which you would have preferred to be alive in England ? Why—or why not ?

OR (*b*) Do you consider that familiarity with English literature and some knowledge of philosophy, ethics and religion are of much importance to the scientist or technician ? Give reasons for your answer.

4. Write a short account of the career and scientific attainments of ONE of the following : Sir Lawrence Bragg, Sir James Chadwick, Lord Cherwell, Sir John Cockcroft.

5. EITHER (*a*) Give the principal arguments for and against the abolition of the death penalty for murder. What is your opinion ?

OR (*b*) Strongly differing opinions were expressed upon the desirability of inviting Marshal Bulganin and Mr. Khrushchev to visit this country officially. What were the various points of view and the arguments used ?

ELECTRONICS

Examiner : A. E. DE BARR, B.SC., F.INST.P.

TUESDAY, 12th June — 2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions, including at least* TWO *from each section*)

The required numerical data are given at the end of the paper

SECTION A

1. Explain how a metal-semiconductor contact can act as a rectifier.

In a thermionic triode currents at a low power level in the grid circuit can be used to control larger currents in the lower impedance anode circuit. Describe briefly how the action of a transistor may be explained in similar terms, and point out the principal points of similarity and difference between the two devices.

2. Explain what is meant by (*a*) secondary emission, (*b*) photoelectric emission.

Describe briefly the principles of operation of an electron multiplier photocell. Indicate suitable materials for the various component parts of the device and discuss its advantages and disadvantages compared with a vacuum photocell followed by a high-gain amplifier.

3. Explain how the potential applied to the suppressor grid of a pentode valve determines the division of the cathode current between the anode and the screen-grid.

What are the advantages of the pentode over (*a*) a triode, (*b*) a tetrode ? Discuss the types of applications for which each of these three types of valve is most suitable.

4. Two identical triodes, with identical anode resistors but with a common cathode resistor, are connected across an h.t. supply. Analyse the action of this circuit and explain how the anode voltages vary when a sinusoidal voltage is applied to one grid, the potential of the other grid remaining constant. Why is it desirable that the resistance in the cathode circuit should be as great as possible ?

Indicate possible uses for this type of circuit.

5. Describe, with diagrams and circuit diagrams to show the essential features, suitable electronic equipment for *two* of the following requirements :—(*a*) a stroboscope is to be synchronized with the rotation of a shaft, the speed of which is fluctuating rapidly ; it is not possible to make contact with the shaft, or to impose any load upon it whilst it is rotating, but minor modifications to the shaft are permissible : (*b*) small articles, uniform in shape and size, pass at a rate of about 1000 per minute along a chute to a point at which they are to be packed in boxes each containing 144 articles ; the stream of articles can be deflected to either of two packaging machines : (*c*) it is required to make a continuous record of the thickness of a strip of paper as it comes off the paper-making machine.

SECTION B

6. Calculate the transit time for an electron in a vacuum diode with parallel plate electrodes 0·5 cm apart, a potential difference of 100 V between the electrodes, and current limited by space charge. Neglect the initial velocities of the emitted electrons.

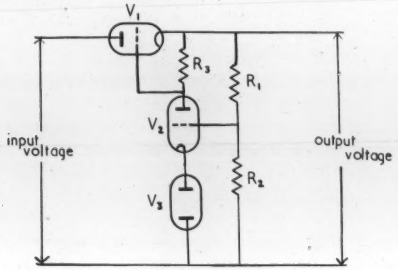
7. The anode current/anode voltage characteristics of a triode valve are given below. The valve is transformer-coupled to a resistive load of 13·3 Ω, the ratio of primary to secondary turns being 20, and is used with an h.t. supply of 400 V. The grid bias voltage is −36 V and a sinusoidal signal voltage of amplitude 30 V is applied to the grid. Calculate (*a*) the percentage of second harmonic in the output voltage, (*b*) the fundamental output power, and (*c*) the efficiency. The resistance of the windings of the transformer may be neglected.

Anode current mA.

Grid voltage	−6	−18	−36	−54	−66
Anode voltage					
50	5				
100	35				
150	90	5			
200	150	25			
250		68			
300		125	7		
350			25		
400			55		
450			100	10	
500				25	
550				50	11
600					25
650					50

8. The anode resistor of a triode valve circuit has a resistance of 50,000 Ω, and so also has the resistor connecting the cathode to the negative terminal of the h.t. supply and earth. The grid is so biased that the anode slope resistance of the valve is 10,000 Ω and the amplification factor is 25. Calculate the approximate value of the internal resistance of (*a*) the anode circuit, (*b*) the cathode circuit, when each is used to drive a subsequent stage of amplification. The input voltage of the triode is applied between grid and earth.

9. The circuit diagram of a series parallel voltage stabilizer circuit is given below. V_1 and V_2 are identical triodes for which $R_a = 40{,}000\ \Omega$ and $\mu = 20$. V_3 is a gas discharge tube. $R_1 = R_2$ and $R_3 = 1\ M\Omega$. Calculate, approximately, the change in the output voltage if the input voltage changes by 10 V.



Numerical data

Electronic charge, e	$1{\cdot}602 \times 10^{-19}$ coulomb
Electronic mass, m	$9{\cdot}107 \times 10^{-28}$ g.

MATHEMATICAL PHYSICS

Examiner : J. Topping, M.Sc., Ph.D., F.Inst.P.

TUESDAY, JUNE 12th—2.00 p.m. to 5.00 p.m.

(*Answer* FOUR *questions*)

1. A light string is stretched tightly between two points at a distance $4l$ apart, and masses m, $2m$, m are attached to the string at points distant l, $2l$, $3l$ respectively from one end.

Find the normal modes of oscillation of the system and the ratios of the amplitudes of the three masses in each normal mode.

2. Show that the displacement z at any point (x, y) of a vibrating membrane satisfies the equation :

$$\frac{\partial^2 z}{\partial t^2} = c^2 \left(\frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2} \right)$$

A rectangular membrane, the edges of which are held fixed, is set vibrating by displacing it into a given form and releasing it from rest. Show how the form of the membrane at any later instant may be found.

3. A straight uniform rod, of known thermal conductivity, density and specific heat, loses heat to its surroundings at a rate proportional to θ, the excess-temperature of the rod above that of the surroundings. Show that θ satisfies the equation

$$\frac{\partial \theta}{\partial t} = k \frac{\partial^2 \theta}{\partial x^2} - \mu \theta$$

where x is measured along the rod, and k and μ are constants of the rod.

If the end, $x = 0$, of the rod is heated in such a way that $\theta = A \cos(\omega t + \alpha)$ when $x = 0$, find the value of θ at any point of the rod at time t.

4. State, without proof, Gauss's divergence theorem and use it to prove that the electrostatic potential V at any point in free space satisfies the equation $\nabla^2 V = 0$. State the boundary conditions which the potential satisfies over a conducting surface having a surface density of charge σ.

An infinite conducting cylinder of radius d is placed in a uniform electric field of intensity E, perpendicular to the axis of the cylinder. Find the potential at any point outside the cylinder, and the surface-density of charge at any point of the cylinder.

5. A magnet of moment **M** is placed at a point P outside a semi-infinite medium of permeability μ, with its magnetic axis normal to the plane boundary of the medium. Show that the magnetic field at any point of the medium is the same as that of a magnet of moment $2\,\mathbf{M}\,(1+\mu)$ placed at P when the medium is removed.

Two magnets, each of moment **M**, are pivoted in free space at points A and B, both distant d from the plane face of the medium and such that $AB = 2d$; show that the moment of the couple which must be applied to each magnet to maintain it normal to the plane face, the magnets pointing in the same direction, is

$$3(\mu - 1)\, M^2/32\sqrt{2}(\mu + 1)\, d^3$$

6. A normally magnetized shell of uniform strength Φ is placed in a magnetic field of intensity **H**. Show that the force on the shell is the same as if a force $\Phi\, \mathbf{ds} \wedge \mathbf{H}$ acted on each element of the boundary curve of the shell. Write down the corresponding result for an element of a circuit carrying a current i.

A rectangular circuit of sides $2a$ and $2b$ carries a current i_1, and is free to rotate about the axis through its centre parallel to the sides of length $2a$. Another current i_2 flows in a very long straight wire parallel to the axis and at a distance c from it. Find the moment of the couple required to maintain the rectangle inclined at an angle θ to the plane through its axis and the straight current.

7. Show that for an electromagnetic field in a homogeneous non-conducting dielectric the electric and magnetic vectors **E** and **H** satisfy the equations

$$\mathbf{Curl\ H} = \frac{k}{c} \cdot \frac{\partial \mathbf{E}}{\partial t} \quad \textit{and} \quad \mathbf{Curl\ E} = -\frac{\mu}{c} \cdot \frac{\partial \mathbf{H}}{\partial t}$$

Hence show that **E** and **H** satisfy the wave-equation.

If the electric vector at any point (x, y, z) at time t is given by $\mathbf{E} = E_0 \sin ay \sin(\omega t - az)\, \mathbf{i}$, where $\mathbf{i}$ is unit vector parallel to the axis of x, and E_0, a, ω are constants, show that $c^2/\mu k = \omega^2/2a^2$ and find the magnetic vector **H**.

8. Show how the laws of relativistic mechanics may be derived using the Lorentz transformation. Explain how the mass, momentum and energy relations are applied to a photon of frequency ν.

A photon of frequency ν is scattered by a free electron at rest. Find the angle between the direction of the incident photon and that of the recoil electron as a function of the final velocity of the electron.

9. A particle of mass m moves in a field of which the potential energy function is zero when $r > a$, and equal to $-V_0$ when $0 \leqslant r \leqslant a$, where V_0 is constant and positive.

Obtain an equation from which the energies of states with spherical symmetry may be calculated. Deduce that there is no bound state with spherical symmetry unless $V_0 a^2 \geqslant \hbar^2/32m$.

NUCLEAR INSTRUMENTATION AND MEASUREMENTS

Examiner : A. E. De Barr, B.Sc., F.Inst.P.

TUESDAY, 12 June—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions, including at least* TWO *from each section*)

The required numerical data are given at the end of the paper

Section A

1. Give an account of the structure of the nucleus, and describe the different types of nuclear reaction that can take place with stable nuclei.

Explain how the energy released in some nuclear reactions is converted into heat energy.

2. Derive the law of radioactive decay from the assumption that the probability that a particular atom of a radioactive element will disintegrate in the short interval of time δt is proportional to δt.

Explain how (*a*) determinations of the ratio of Pb^{206} to Pb^{207} in minerals enable estimates of the age of the earth to be made, (*b*) determinations of the proportion of C^{14} to C^{12} in materials of organic origin enable the age of the material to be estimated.

3. Describe the construction and operation of a scintillation counter for measuring the energies of β-particles and γ-rays. Explain the factors that determine (*a*) the choice of phosphor, (*b*) the lowest energy particles that can be detected.

4. Describe and explain the equipment you would use with an ionization chamber in order to (*a*) measure a saturation current of 10^{-15} amp, (*b*) count the α-particles from a radioactive source.

Indicate the factors that limit the performance of each portion of the equipment you describe.

5. Describe the action of the different types of circuit that may be obtained by varying the method of interstage coupling in a two-stage untuned amplifier in which the whole of the output voltage is fed back to the input.

Explain briefly the use of a circuit of this type for (*a*) generation of square waves at 10 c/s, (*b*) a scale-of-ten counter.

Section B

6. Calculate (*a*) the maximum velocity that can be imparted to an electron by impact with an α-particle of energy 6 MeV, (*b*) the weight of one curie of P^{32} (half-life 14·3 days), (*c*) the average velocity of a thermal neutron at 25°C, (*d*) the thickness of cadmium necessary to reduce a beam of thermal neutrons to 0·1% of its initial intensity.

7. An ionization chamber has a volume of 50 cm^3 and contains air at atmospheric pressure. The saturation current flows through a resistance of 10^{11} Ω and a valve voltmeter is used to measure the potential difference across this resistance. When the ionization chamber is placed 30 cm from a source of 1 MeV γ-radiation, the potential difference across the resistance is 1 volt. Calculate (*a*) the strength of the source, in curies, (*b*) the minimum thickness of lead that must be placed around this source in order to allow a man to work at 1 m from it for two hours each day. (Assume a maximum daily tolerance rate for any part of the body of 0·05 r.)

8. The window of an end-window Geiger counter has an effective area of 2 cm^2 and is covered with aluminium foil of thickness 0·001 cm. The counter is used, with suitable auxiliary equipment, to count particles from a source emitting β-particles of maximum energies 2·0 MeV and 0·5 MeV. The time to record 10,000 counts is measured with the counter at different distances from the source, the following results being obtained :—

Distance from source to counter, cm	30	40	60	80	100	120	140	160	180
Time for 10,000 *counts, seconds*	2·5	5·2	20·4	49·6	95·0	161	245	358	504

With source removed, the time for 10,000 counts was 8000 seconds.

Calculate (*a*) the half-value thickness, in $g.cm^{-2}$, of air for each component of the radiation, (*b*) the total activity of the source.

9. The background counting rate of a counter is measured and 600 counts are recorded in 15 minutes. A palladium foil of thickness 0·001 cm containing Pd^{109} is then placed close to the window and 3260 counts are registered in 10 minutes. With a palladium foil of the same specific activity but 0·1 cm thick in front of the window of the counter, 19,540 counts were recorded in 10 minutes. When a 0·1 cm thick palladium foil of different specific activity is placed in front of the counter, 3000 counts are registered in 5 minutes.

Calculate (*a*) the resolving time of the Geiger counter, (*b*) the ratio of the specific activities of the two samples of palladium, and the standard deviation of this ratio. (Pd^{109} emits only β-particles with maximum energy 0·95 MeV.)

Numerical Data

Absorption data

Radiation	*Energy MeV*	*Absorber*	*Density* $g.cm^{-3}$	*Half-thickness* $g.cm^{-2}$
β	0·5	Aluminium	2·7	0·012
β	2·0	Aluminium	2·7	0·08
β	0·95	Palladium	11·9	0·05
γ	1·0	Lead	11·4	14·3
γ	1·0	Air	$1{\cdot}293.10^{-3}$	15·7
Neutrons	Thermal	Cadmium	8·6	$\sigma = 2900$ barns

Electronic charge, e	$4{\cdot}8.\ 10^{10}$ e.s.u.
Electronic mass, m	$9{\cdot}107.\ 10^{-28}$ g.
Velocity of electromagnetic waves in free space	$3{\cdot}\ 10^{10}$ cm sec^{-1}
Boltzmann's constant, k	$1{\cdot}38.\ 10^{-23}$ joule per °K
Energy required to form an ion-electron pair in air	32·5 eV
Atomic mass unit	$1{\cdot}660 \times 10^{-24}$ g.

SPECTROSCOPY

Examiner : A. E. De Barr, B.Sc., F.Inst.P.

TUESDAY, 12th June—2.00 p.m. to 5.00 p.m.

(*Answer* five *questions, including at least* two *from each section*)

The required numerical data are given at the end of the paper

Section A

1. Describe and explain, with reference to atomic and molecular structure, the nature of atomic spectra and molecular spectra.

How are atomic and molecular spectra influenced by (*a*) temperature (*b*) pressure (*c*) electric and magnetic fields ?

2. Discuss the use of (*a*) radiometric, (*b*) photoelectric methods for the measurement of spectral intensities. Refer particularly to the sensitivity, linearity and wavelength range of each of the devices you describe.

3. Describe carefully the procedure you would adopt to determine spectrographically the amount of iron in a sample of liver. Give your reasons for the choice of each feature of the method described, and indicate the accuracy you would expect to achieve.

4. Discuss the problems involved in investigating the fine structure of spectral lines, and describe apparatus suitable for use in investigating the fine structure of a line of wavelength about 2000 Å.

5. Describe, giving constructional details and essential dimensions, one form of infra-red spectrometer suitable for routine analyses of hydrocarbon mixtures. Indicate briefly the procedure you would adopt to determine the proportions of the various constituents in such a mixture.

What factors limit the sensitivity and the useful wavelength range of such a spectrometer ?

Section B

6. The dispersing element of a spectrograph is a 60° prism of base length 10 cm. At minimum deviation the angular dispersion of this prism, at a wavelength of 3580 Å, is 2840 radians cm^{-1}. The spectrograph is used to record the spectrum, in the region around 3580 Å, of a spark source, the entrance slit being illuminated by an image of the source produced by a condensing lens of focal length 4 cm. The collimator lens has an aperture ratio of *f*/10 and a focal length of 25 cm. The entrance slit is 5 mm long and 0·05 mm wide.

Assign suitable values to any other quantities involved, and calculate (*a*) the required aperture ratio for the condensing lens, (*b*) the distance from the condensing lens to the entrance slit, (*c*) the length of the image on the plate, (*d*) the wavelength interval in the spectrum covered by a single slit image.

7. A concave grating of ruled width 6 inches and with 25000 lines per inch is to be used in conjunction with a photographic plate capable of resolving 30 lines per mm. It is required to be able to separate two lines with an interval of 0·016 Å and a mean wavelength of 5206 Å.

Calculate (*a*) the required radius of the grating, (*b*) the separation, on the photographic plate, of the sodium D lines (5895·923 Å and 5889·953 Å), (*c*) the effective aperture ratio of the instrument, using a suitable type of mounting for the grating.

8. Estimate the resolving power of a 60° quartz prism of base length 8 cm at a wavelength for which the minimum deviation is 45°. The resolving power at 6563 Å is 1.9×10^3, and at minimum deviation a ray of this wavelength is deviated 41°. Quartz has an absorption band at 1030 Å.

9. A microdensitometer is adjusted so that the galvanometer reading is proportional to the amount of light transmitted through the plate under examination. The galvanometer is arranged to read 100 when the light passes through an unexposed portion of the plate. Two identical photographic plates are exposed with a neutral step filter in front of the entrance slit of a prism spectrograph with a prism of medium phosphate crown glass. The following galvanometer readings are obtained when the two plates are measured in the microdensitometer at positions on each plate corresponding to wavelengths of 7000 Å and 5250 Å.

Step-filter section	1	2	3	4	5	6	7	8
Plate I 7000 Å ...	100	100	91·0	75·6	55·5	30·2	12·0	4·0
5250 Å ...	39·9	20·0	11·0	5·3	2·5	1·4	0·7	0·5
Plate II 7000 Å ...	48·3	23·0	7·2	2·5	1·0	0·5	0·3	0·2
5250 Å ...	100	100	100	100	87·0	58·1	33·1	15·9

The step filter is such that the exposure through each section is twice that through the preceding section.

Plate I records the line spectrum from a spark source and Plate II records the continuous spectrum from a black-body source at 1155°C.

Calculate the ratio of the intensities of the two lines of the spark spectrum at 7000 Å and 5250 Å.

Numerical Data

Planck's First Radiation Constant 1·177. 10^{-12} watts cm^{-2}
Planck's Second Radiation Constant 1·432 cm. °K.

Refractive index of medium phosphate crown glass

Wavelength	*Refractive index*	$dn/d\lambda$
cm	n	cm^{-1}
$7.\ 10^{-5}$	1·5577	267
$5{\cdot}25.\ 10^{-5}$	1·5650	631

STATISTICS

Examiner : E. D. VAN REST, M.A., B.Sc., F.INST.P.

TUESDAY, 12th June—2.00 p.m. to 5.00 p.m.

(*Candidates should attempt not more than* FOUR *questions. The four should include at least* ONE *from Section A*)

SECTION A

1. The following are the weights (to the nearest 0·01 oz.) of zinc coating determined by a chemical method on 75 test-pieces of galvanized iron.

1·47	1·60	1·58	1·56	1·44
1·62	1·60	1·58	1·39	1·35
1·52	1·38	1·32	1·65	1·53
1·77	1·73	1·62	1·62	1·38
1·55	1·70	1·47	1·53	1·46
1·53	1·60	1·42	1·47	1·44
1·38	1·60	1·45	1·34	1·47
1·37	1·48	1·34	1·58	1·43
1·64	1·51	1·44	1·49	1·64
1·46	1·53	1·56	1·56	1·50
1·63	1·59	1·48	1·54	1·61
1·54	1·50	1·48	1·57	1·42
1·53	1·60	1·55	1·67	1·57
1·34	1·54	1·64	1·47	1·75
1·60	1·57	1·57	1·63	1·47

Group into about ten convenient weight classes and compare the frequencies in these classes with those for a normal distribution with the same mean and standard deviation.

2. The weight of a sample of fibre drying in a chamber determined at the same hour of each of four days is given as :—Saturday 44·231 g ; Monday 44·025 g ; Tuesday 43·901 g ; Wednesday 43·803 g. Assuming that over these few days the rate of drying is uniform, make an estimate of the weight on the Sunday, the day for which no weighing was made. Would it be preferable to base a Sunday estimate on weighings made on four week-days from Friday to Tuesday rather than the four given ? Give reasons for your answer.

3. State the conditions under which a Poisson variate is generated.

A firm provides a car with three passenger seats to make one journey each day from factory to H.Q. If there is a large number of individuals likely to make a booking yet the average demand is only for 1·8 seats a day, what evidence can be produced from these facts which would help to decide whether the purchase of a car with four or a car with five passenger seats would be advantageous ? In each case (three, four, five passenger seats) on what proportion of days would it be expected that demands would have to be refused ? What is the daily average of refused demands ?

Section B

4. An electronic device has the heaters of its four valves connected in series. The device will continue to function even when two of its valves are out of action. The heaters are known to have lives normally distributed about 900 hours with a standard deviation of 60 hours. Considering only the failure of the heaters, what change in the risk of failure of the device before 840½ hours can be brought about by connecting the heaters in parallel so that failure of one does not cause all four to cease functioning ?

5. Glass rod of average diameter 1 cm, is cut into short pieces and weighed. Each piece may be considered to have constant dimensions over its length. The weights are found to be distributed normally about a mean 9 g with a variance 0·2025 g^2. The lengths are known to be normally distributed about 5 cm with a variance 0·01 cm^2. Give a general formula for estimating from such information the variance of the distribution of diameter and make the estimate in this case.

6. Write briefly about ONE of the following :—

The control chart technique ; the randomized block layout of experiments ; the relation of the correlation coefficient to the linear regression coefficient.

7. It has been shown that a variate subject to numerous causes of small deviations, equally likely to be of either sign, is normally distributed. Use this fact to relate the binomial and the normal distributions and to explain (*a*) why and under what conditions the normal might be expected to be a good approximation to the binomial distribution and (*b*) why the distribution of averages from a non-normal distribution tends towards normality as the number averaged ncreases.

Samples of 200 articles are repeatedly taken at random from lots containing 5% defective. What proportion of such samples would be expected to contain (i) more than 10 defective, (ii) more than 194 correct articles ?

8. Two chemists each make several individual fillings and weighings of a specific gravity bottle using the same bulk solution. They record the following corrected weights in grams :

A — 42·850 ; 43·062 ; 43·043 ; 42·941 ; 42·956

B — 42·957 ; 42·926 ; 42·925 ; 42·682 ; 42·820

Is there evidence of bias of one relative to the other ?

What modifications of your analysis would you make if you suspected or were told that each set of readings was made with five different bottles, the same bottles being used in the same order by the two men ?

X-RAYS

Examiner : A. E. De Barr, B.Sc., F.Inst.P.

TUESDAY, 12th June—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions, including at least* TWO *from each section*)

The required numerical data are given at the end of the paper

Section A

1. Explain, with reference to the atomic structure of the anode material, the changes in the nature of the radiation emitted from an X-ray tube as the voltage applied between the anode and cathode of the tube is increased.

How must your explanation be modified if the atomic number of the target element is altered ?

2. Indicate, very approximately, the proportion of the electrical energy supplied to an X-ray tube that appears as characteristic X-radiation. What happens to the remainder of the energy ?

Discuss the significance of these answers in relation to the design of X-ray tubes for X-ray crystallography, and describe the physical principles involved in (*a*) cooling the anode of an X-ray tube, (*b*) ensuring maximum utilization of the available X-ray energy.

3. Describe and discuss three ways in which X-rays can be used for analysis of the composition of an alloy.

4. Discuss the application of X-ray radiographic methods of inspection to (*a*) examination of welds in thick steel plates, (*b*) monitoring of the contents of cardboard packages for unwanted metallic inclusions.

Describe, for each application, the equipment and technique to be used, and indicate how you would determine the appropriate X-ray tube voltage and current.

5. Write an account of the methods used for the production of very high voltage X-rays.

Section B

6. An ionization chamber has a volume of 50 cm^3 and contains air at atmospheric pressure. The saturation current flows through a resistance of 10^{11} Ω and a valve voltmeter is used to measure the potential drop across this resistance. When the ionization chamber is placed 30 cm from the target of a 1 MeV X-ray tube the potential drop across the resistance is 1 V.

Calculate (*a*) the minimum thickness of lead (mass absorption coefficient $4{\cdot}86.\ 10^{-2}\ cm^2\ g^{-1}$) that must be placed between the tube and a man who has to work for two hours each day at a distance of 1 m from the tube, (*b*) the energy per cm^2 per second in the X-ray beam, given that the mass absorption coefficient of air for this radiation is $0{\cdot}1\ cm^2\ g^{-1}$.
(Assume a maximum daily tolerance rate, for any part of the body, of 0·05 r.)

7. Two identical photographic films are exposed, a section at a time, to radiation from an X-ray tube operated in a self-rectifying circuit from the a.c. mains via a step-up transformer such that the peak voltage applied to the tube is 100 kV when the voltage across the primary winding is 240 V. An auto-transformer enables the voltage applied to the primary winding to be varied. A parallel-sided slab of an aluminium alloy is placed between the tube and the films, which are exposed under the conditions given below. Densitometry of the two films in

a densitometer adjusted to read zero with no light reaching the photocell, and to read 100 with a clear portion of the film in the path of the light, gives the following results :—

Film 1. X-ray tube voltage 70 kV ; X-ray tube current 20 mA.
The exposure time for each section is twice that for the preceding section :

Section	1	2	3	4	5	6
Densitometer reading	38·0	20·9	7·4	2·1	0·6	0·2

Film 2. X-ray tube current 20 mA.
Exposure time constant but the voltage across the X-ray tube varied :

Section	1	2	3	4	5	6
Tube voltage kV	40	50	60	70	80	90
Densitometer reading	31·6	11·8	3·2	1·1	0·4	0·2

Investigate the variation of the absorption in the aluminium alloy with X-ray tube voltage, and hence determine the X-ray tube current that will enable the parallel-sided specimen to be radiographed at a nominal 90 kV with the minimum exposure time if the X-ray tube is operated under circumstances such that the internal resistance of the 250 V a.c. mains supply is 0·5 Ω.

8. A lead screen with two pinholes 10 cm apart is placed parallel to and at a distance of 25 cm from a photographic plate. An X-ray tube is placed on the other side of the screen with its anode on a line perpendicular to the screen and midway between the two pinholes. The images of the focal spot on the film are 18·8 cm apart, and are 2·6 × 1·76 mm and 0·84 × 1·76 mm in length and width respectively.

Calculate (*a*) the size of the focal spot, (*b*) the inclination of the face of the anode of the X-ray tube to the plane of the screen.

9. On a powder photograph of a cubic element taken with unfiltered cobalt K radiation, lines were observed corresponding to the following Bragg angles :—

22° 51′, 25° 24′, 26° 38′, 29° 42′, 39° 21′, 44° 28′, 48° 1′,
50° 56′, 55° 14′, 59° 6′, 63° 42′, 77° 42′, 81° 46′, 82° 41′.

Given that the density of the element is 8·9 g.cm^{-3}, calculate its atomic weight.

Numerical Data

X-ray wavelengths Å

	$K\alpha_1$	$K\alpha_2$	$K\beta$
Cobalt	1·78529	1·78919	1·61744

Densities g.cm^{-3}

Lead : 11·4 Air at N.T.P. : 1·293. 10^{-3}

Energy required to form an ion-electron pair in air : 32·5 eV
Velocity of electromagnetic waves in free space : 3. 10^{10} cm.sec^{-1}
Electrostatic unit of potential difference : 300 volts
Atomic mass unit : 1·660 × 10^{-24} g.

MATHEMATICS I

Examiner : J. Topping, M.Sc., Ph.D., F.Inst.P.

WEDNESDAY, 13th June—9.30 a.m. to 12.30 p.m.

(*Answer* six *questions*)

1. Show that the equation $x^4 - 7x + 3 = 0$ has only two real roots and that both are positive.

Show that one root equals 3/7 approximately, and find this root correct to three decimal

places by iteration on $x = \frac{1}{7}(3 + x^4)$.

Find the other root, by Newton's method, correct to four significant figures.

2. A coil of n turns of radius r carries a current I; the magnetic field at a point on its axis at a distance x from the centre is $H = 2\pi nr^2 I(r^2 + x^2)^{-3/2}$. If the error in measuring x is e, find the corresponding error in the calculated value of the field. If e is constant find for what value of x the error in H is greatest.

Also, if the percentage error in x is constant find for what value of x the percentage error in H is greatest.

3. (*a*) Obtain a reduction formula for the integral

$$\int_0^{\frac{1}{2}\pi} x^n \cos mx \, dx$$

when $n \geqslant 2$, and evaluate

$$\int_0^{\frac{1}{2}\pi} x^5 \cos 3x \, dx$$

(*b*) If $I = \int_0^{\pi} \log_e (1 + a \cos x) \, dx$

find $\frac{dI}{da}$, and hence evaluate I given that $0 < a < 1$

4. The currents x and y in two circuits satisfy the equations

$$7\frac{dx}{dt} + 4\frac{dy}{dt} + 50x = E$$

$$4\frac{dx}{dt} + 5\frac{dy}{dt} + 20y = 0$$

where E is a constant.

Find x and y given that $x = 0$ and $y = 0$ when $t = 0$, and sketch the graph of x against t.

5. If $x + iy = a \cot(u + iv)$ prove that

$$\frac{x}{\sin 2u} = \frac{-y}{\sinh 2v} = \frac{a}{\cosh 2v - \cos 2u}$$

Show that the curves $v =$ constant in the (x, y) plane are the circles $x^2 + y^2 + 2ay \coth 2v + a^2 = 0$

If r_1, r_2 are the radii of the circles corresponding to $v = v_1$ and $v = v_2$ respectively, show that the distance d between their centres is given by

$$(r_1^2 + r_2^2 - d^2)/2r_1 r_2 = \cosh 2(v_1 - v_2)$$

6. If the function $f(x)$ is expanded in the form $\sum_{r=0}^{\infty}(a_r \cos rx + b_r \sin rx)$ over the range 0 to 2π find a_0, a_r and b_r.

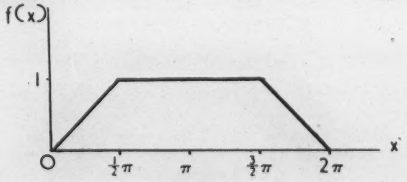


FIG. 1.

Evaluate these coefficients when $f(x)$ is the function represented in Fig. 1.

Sketch the function represented by the series for values of x from 0 to 6π.

7. If A, B and H denote the moments and product of inertia of a lamina relative to axes Ox, Oy, prove that the product of inertia with respect to other rectangular axes Ox', Oy' is $\frac{1}{2}(A-B)\sin 2\theta + H\cos 2\theta$ where θ is the angle xOx'. Deduce the directions of the principal axes at O.

A thin plate, bounded by the ellipse $\frac{x^2}{a^2}+\frac{y^2}{b^2}=1$ is divided into four equal parts by cuts along the x-axis and the y-axis. Find the principal axes of inertia at the origin for one of these parts.

8. A body is projected under gravity with velocity V at an angle θ to the horizontal, and is subject to a resistance equal to k times its velocity per unit mass. Find the equation of its path.

Show that, if k is so small that squares and higher powers can be neglected, the range on the horizontal is reduced owing to the resistance by an amount $8kV^3 \sin^2\theta \cos\theta/3g^2$.

9. A ring of mass m can slide on a smooth horizontal wire and is attached by an elastic string of natural length l and modulus of elasticity kmg to a point at a distance $d(>l)$ from the wire. The ring is displaced a distance b along the wire from its equilibrium position and then released from rest ; describe the ensuing motion and find the greatest velocity of the ring.

If the distance b is small compared with d, find the time taken for the particle to return to its initial position.

MATHEMATICS II

Examiner : J. Topping, M.Sc., Ph.D., F.Inst.P.

WEDNESDAY, 13th June—2.00 p.m. to 5.00 p.m.

(*Answer* six *questions*)

1. (*a*) Express $\dfrac{1+2x}{(1+x^2)(1-3x)}$ in partial fractions, and find the general term in the expansion of the function in ascending powers of x. For what values of x is the expansion valid ?

(*b*) Sum the infinite series

$$\sum_{n=0}^{\infty}\frac{\cos n\theta}{2^n} \text{ and } \sum_{n=0}^{\infty}\frac{\cos n\theta}{n!}$$

2. Given that the likelihood of the occurrence of the set of measurements $x_1, x_2, \ldots x_n$ is proportional to

$$P=(h/\sqrt{\pi})^n \; e^{-h^2 \Sigma (x_i-\bar{x})^2}$$

where $\bar{x}$ is the arithmetic mean of the measurements, find the value of h for which P is a maximum.

A set of data is distributed as shown below, where f denotes the frequency with which the measurement $\bar{x}$ occurs. Calculate the value of h for which P is a maximum for this set of measurements.

x	15	16	17	18	19	20	21	22	23	24
f	1	5	17	49	85	52	25	11	4	1

3. (*a*) Verify that the line-integral $\int (x^2\,dy - y^2\,dx)$ round a closed path C equals the double integral $\iint 2(x+y)\,dx\,dy$ over the area bounded by C, when C is the ellipse

$$x = 2 + 3\cos t,\ y = 2\sin t.$$

(*b*) Evaluate $\iint \frac{x\,dx\,dy}{(4+x^2+y^2)^2}$ over the circle $x^2+y^2 \leqslant 4$, by transforming to polar coordinates.

4. (*a*) If $x = uv$ and $y = u + v$ prove that

$$\frac{\partial x}{\partial v} \cdot \frac{\partial v}{\partial x} = \frac{u}{u-v} = \frac{\partial y}{\partial u} \cdot \frac{\partial u}{\partial y}$$

(*b*) If $\psi = f(r)\sin^2\theta$, where $f(r)$ is a function of r only, is a solution of

$$r^2 \frac{\partial^2 \psi}{\partial r^2} + \sin\theta \frac{\partial}{\partial \theta}\left(\frac{1}{\sin\theta}\frac{\partial \psi}{\partial \theta}\right) = 0,$$

show that $r^2 \frac{d^2 f}{dr^2} - 2f = 0$. By using the substitution $f = Ar^n$, or otherwise, find f.

Deduce a solution of the original equation which is such that $\psi = 0$ when $r = a$ for all values of θ.

5. (*a*) Show that the length of one branch of the curve $4y^2 = x^5$ from $x = 4$ to $x = 9$ is given by

$$\tfrac{1}{4}\int_4^9 (16 + 25x^3)^{\frac{1}{2}} dx$$

By expanding the integrand as a series, or otherwise, evaluate the integral correct to two decimal places.

(*b*) The function $f(x)$ is tabulated as follows :

x	$f(x)$	x	$f(x)$
1·0	0·64147	1·5	0·79749
1·1	0·69121	1·6	0·79957
1·2	0·73204	1·7	0·79166
1·3	0·76356	1·8	0·77385
1·4	0·78545		

Find $f(x)$ when $x = 1{\cdot}03$ and $x = 1{\cdot}74$. Find also the differential coefficient of $f(x)$ when $x = 1{\cdot}35$.

6. (*a*) Prove that $m\,\mathbf{OA} + n\,\mathbf{OB} = (m+n)\,\mathbf{OC}$, if C is the point on AB such that $m\,AC = n\,CB$.

The vertices of a uniform solid pyramid are the points (0, 0, 0), (3, − 1, 2), (2, − 3, 5), (3, 4, 5) respectively. Find vectorially the coordinates of its centre of gravity.

(*b*) Define the vector-product $\mathbf{a} \wedge \mathbf{b}$ of two vectors $\mathbf{a}$ and $\mathbf{b}$ and find an expression for this product in terms of the components of the two vectors parallel to the axes of x, y and z.

Find the vector-product $\mathbf{AB} \wedge \mathbf{CD}$ given that A, B, C, D are the points (5, 7, − 2), (2, 8. − 3), (− 3, 3, 6) and (0, 1, 2) respectively. Deduce the shortest distance between the lines AB and CD.

7. Discuss the application of the principle of virtual work to the solution of certain statical problems.

Four equal uniform rods of length a and weight w are freely jointed together to form a rhombus $ABCD$. The frame is freely suspended from A and a weight w' is attached to C. A rod EF of negligible weight joins the middle points of AB and AD, keeping these inclined at an angle θ to AC. Show that the thrust in the rod EF is $(4w + 2w')\tan\theta$.

Find also the reaction at the joint B.

8. Derive the radial and transverse components of the acceleration of a particle moving in a plane.

A particle of mass m is projected from infinity with velocity V directed along the line $x = p$, and is repelled by a centre of force at the origin O with a force km/r^2 where r is the distance of the particle from O.

Examine the path of the particle and find the angle through which the particle is ultimately deflected.

9. A heavy uniform cylinder of radius r begins to move along a rough horizontal table with velocity V perpendicular to its axis, and with an initial angular velocity Ω in the sense that would tend to make it roll backwards. Show, if $V > \frac{1}{2}r\Omega$, the direction of rotation is reversed after a time $r\Omega/2\mu g$ and that rolling begins after a further interval $(V - \frac{1}{2}r\Omega)/3\mu g$, where μ is the coefficient of friction between the cylinder and the table.

Describe the motion when $V < \frac{1}{2}r\Omega$.

PRACTICAL PHYSICS

Examiners :

A. E. De Barr, B.Sc., F.Inst.P. ; J. Yarwood, M.Sc., F.Inst.P.

FRIDAY, 15th June

(Six hours allowed)

(Two questions, selected by the Examiners, will be allotted to each candidate)

1. Find the thermal conductivity of rubber in the form of a tube.

2. Determine Young's modulus for the material of the bar provided using a strain gauge.

3. Calibrate the thermocouple gauge for air pressures in the range 10^{-3} to 1 mm of mercury using a McLeod gauge.

4. Make an aluminized front-surface mirror and determine its reflectivity for a beam of white light incident at an angle of 45°.

5. Determine Planck's quantum of action h using a photoelectric cell.

6. Find the self-inductance of the coil provided using an a.c. bridge.

7. Find the wavelength in alcohol of a propagated wave of ultra-sound using an optical diffraction method.

8. Find the dispersive power of the glass of the given lens. Use a second lens of the same material placed at the correct distance calculated to give minimum chromatic aberration. Determine the difference in magnification of the blue and red images for any convenient position of the object placed before this combination of lenses.

9. Find for the radioactive source provided (*a*) the half-life period, and (*b*) the range in air at atmospheric pressure of the particles emitted.

10. Find the mean diameter of the particles of the powder provided using two different methods.

The Institute's Journals

PRINCIPAL CONTENTS OF THE SEPTEMBER, 1956, ISSUES

Journal of Scientific Instruments: Volume 33, No. 9

PAPERS

A portable temperature-chlorinity bridge for estuarine investigations and sea water analysis. By B. V. Hamon (*Division of Electrotechnology, National Standards Laboratory, Commonwealth Scientific and Industrial Research Organization, Australia*).

An instrument for the measurement of temperature and chlorinity of water *in situ* is described. A thermistor is used for temperature measurement, and an electrical conductivity cell, the temperature coefficient of which is compensated by means of the thermistor, is used for chlorinity. The instrument is direct reading, with ranges of 0–30°C for temperature and 0–16 p.p.t. (parts per thousand) and 16–20 p.p.t. for chlorinity. The accuracy is ±0·1°C for temperature, and ±0·05 p.p.t. for chlorinity on the higher range. When used in the laboratory as a transfer instrument, an accuracy of ±0·02 p.p.t. in chlorinity can be obtained.

The measurement of film thickness with a pneumatic hypodermic needle mechanism. By N. Stolow (*Courtauld Institute of Art, University of London, London, W.1*).

An apparatus is described by means of which the measurement of film thickness may be made on supported polymer films in a non-destructive manner. This apparatus is based on the principle of flow of a gas, e.g. nitrogen, through the space formed by the tip of a cut-off hypodermic needle and a given surface. The theory, an extension of a previous one for a swelling measurement apparatus, is presented and appropriate sensitivity expressions are derived. Agreement with the theory is good except when the rate of flow parameter is high, and kinetic energy corrections must then be applied. The r.m.s. error in the location, at a fixed distance away, of a point on a surface is found to be ±0·2 μ. The films are ordinarily cast on optically selected flat-faced glass plates which are mounted on the flat base plate of the apparatus. By lateral sliding action of the support on the base plate, a number of surface locations are made on the film and around the film edge from which the mean film thickness is obtained. The r.m.s. error in the mean film thickness is found to be ±0·4 μ for films ranging from 10 μ to greater than 200 μ in film thickness.

A semi-conducting antimony bolometer. By E. J. GILLHAM (*National Physical Laboratory, Teddington, Middlesex*).

Thin films of a semi-conducting form of antimony prepared by sputtering from a cathode of metallic antimony are suitable, with regard to resistivity, temperature coefficient of resistance and freedom from current noise, for the construction of bolometers of good sensitivity and of sufficiently high resistance for matching into a valve amplifier. A description is given of the construction and performance of such a bolometer, in which the antimony film is deposited on a thin plastic pellicle.

A photoelectric microscope for the measurement of linear scales. By J. S. Clark and A. H. Cook (*National Physical Laboratory, Teddington, Middlesex*).

A description is given of a photoelectric microscope which is suitable for the accurate measurement of linear scales of high precision. A real image of a graduation line, formed by means of an ordinary microscope objective, is caused to oscillate across a fixed slit in front of a photoelectric cell. A phase-sensitive rectifier determines when the mean position of the line image coincides with the centre line of the slit. When this is so, the d.c. output of the rectifier is zero and for small displacements of the mean position of the line image, the d.c. output—which is measured on a microammeter—is proportional to the displacement.

The standard deviation of a single setting of the microscope is about 0·03 μ and by associating the microscope with an interferometer, short linear scales have been measured directly in wavelengths with a standard deviation of about 0·1 μ. It is thought that, with a properly designed interferometer to measure the displacement of a scale with respect to a fixed photoelectric microscope, a standard deviation of 0·05 μ would be achieved.

On preparing plastic copies of diffraction gratings; an extension to the Merton-N.P.L. process. By G. D. Dew (*National Physical Laboratory, Teddington, Middlesex*).

A process is described whereby a number of glass-based plastic copies may be prepared from a Merton-N.P.L.

gelatine replica grating. These copies, considerably more stable than the gelatine replicas, may be employed as transmission gratings or aluminized and used by reflection. By using plate glass blanks it is possible to reduce production costs while obtaining an optical quality almost indistinguishable from that of the parent replica. For moiré fringe counting applications the process may be employed in preparing copies many times the length of the original grating, all the sections being parallel and in phase. Copies prepared in this way may be recopied a number of times by the use of a slightly modified process.

A microwave thermistor calorimeter. By M. J. Smith, Grad.Inst.P., and J. R. M. Vaughan (*E.M.I. Research Laboratories Ltd., Hayes, Middlesex*).

The instrument described is an improved continuous-flow water calorimeter for the measurement of microwave powers from a few milliwatts upwards. Thermistors are used to measure the temperature rise of the water; their small size and high sensitivity allows the calorimeter to be relatively rugged, accurate and quick reading. The circuit is a direct reading d.c. bridge, indicating on a microammeter specially calibrated in degrees of temperature rise, and in watts of microwave power at a standard water flow rate. A mathematical analysis is given of the four-thermistor bridge, the compensation for variations of ambient temperature, and the correction for internal heat losses. Details are given of the practical method of setting the calibration and determining the cooling correction. Accuracy is thought to be better than $\pm 10\%$ for powers over 1 W at 8-9 mm wavelength, with a reading time of a few seconds.

An instrument for measuring absorptivities for solar radiation. By H. Tabor, A.Inst.P., and I. T. Steinberger (*National Physical Laboratory of Israel, Jerusalem, Israel*).

An instrument and method for measuring solar absorptivities of prepared metal samples is described. By means of comparing the cooling and heating cycles, when subjected to solar radiation, of a sample plate of which one side is a standard black and the other is the test surface, most of the usual errors are eliminated and a direct comparative measure of absorptivity obtained.

LABORATORY AND WORKSHOP NOTES

A d.c. arc chamber for radioactive materials. *By* F. T. Birks *and* R. P. Thorne.

A gas introducer for a vacuum system. *By* H. A. Wyllie.

A method for comparing ultrasonic velocities in solids and liquids using a spectrometer. *By* G. M. Sreekantath *and* A. O. Mathai.

A modified flap-type vacuum valve. *By* H. M. Buck.

Adhesives for galvanometer mirrors. *By* N. W. Sullivan.

A microwave amplitude stabilizer. *By* S. J. Fray *and* M. F. Kimmitt.

CORRESPONDENCE

A simple bridge circuit for the accurate measurement of pulse impedance. *From* J. B. Gunn.

Temperature controller for an electric furnace. *From* R. W. Christy.

British Journal of Applied Physics: Volume 7, No. 9

SPECIAL ARTICLE

Crystallography and the phase rule. By Prof. A. R. Ubbelohde, F.R.S. (*Imperial College of Science and Technology, London*).

Classical thermodynamics provides powerful methods for correlating various thermal parameters of a system. However anomalies are found in the classical theory particularly for condensed phases, such as solids or liquids. A detailed study of the structure of such phases by what may be broadly termed crystallographic methods has thrown much light on the classical anomalies. The present review surveys various structural changes, such as crystal lattice transformations or melting, that produce increases of entropy and thus can favour thermodynamic transitions in solids. Particular attention is directed towards the structural elucidation of the following anomalies:

(i) Pre-transition and pre-melting phenomena. In many cases these can now be attributed to gradual structural changes within a crystal of the same kind as the discontinuous jump at a transition.

(ii) The occurrence of smeared or continuous thermodynamic transitions, which are sometimes described as transitions of "higher order." These can often now be attributed to the coexistence of regions of two slightly different structures or sub-units within

a hybrid single crystal. Reference is made to some of the techniques of study that have been used to investigate such coexistence.

(iii) The occurrence of hysteresis around a thermodynamic transition. This can arise from the same coexistence phenomena that lead to smeared thermodynamic transitions.

Precision studies on single crystals of the kinds described seem likely to throw much light on thermodynamic transitions in solids.

Papers

Preparation of scattering foils of uranium by evaporation of the metal in high vacuum.

By K. K. Damodaran (*Physics Department, University College, London*).

Scattering foils of uranium were prepared by evaporating uranium in high vacuum and depositing it on thin backing foils of aluminium. The average thickness of each foil was determined by direct weighing. The variation in thickness of each of the foils was measured by counting the α- and β-radiations emitted by uranium from the various parts of the foil, using a Geiger-Müller counter.

The viscosity of mixtures of gases at high temperatures.

By M. J. Kenney, Grad.Inst.P., R. J. Sarjant and Prof. M. W. Thring, F.Inst.P. (*University of Sheffield*).

An accurate knowledge of the high temperature viscosity of mixtures of gases, such as the products of fuel combustion, is desirable for heat transfer calculations. The viscosities of mixtures of carbon dioxide and nitrogen were determined up to 900°C by a method in which the rate of fall of gas pressure in a closed, heated container is observed over a short period during which the gas is flowing out to the atmosphere along a heated capillary tube. A comparison is made between the experimental values obtained and those calculated for similar gas mixtures on the basis of a modern theory of transport coefficients. This comparison shows that it is possible to calculate the viscosities of gas mixtures at high temperatures with an accuracy of at least 2%.

Focal properties and chromatic and spherical aberrations of the three-electrode electron lens.

By G. D. Archard (*Research Laboratory, Associated Electrical Industries Ltd., Aldermaston, Berkshire*).

Published theoretical and experimental values of the *focal lengths* of simple three-electrode electron lenses are compared and found to be in general agreement. These are presented in the form of graphs which show directly the dependence of focal length on lens geometry and voltage ratio. Analogous graphs are derived for *spherical* and *chromatic* aberrations in the form of the ratios C_s/S and C_c/S (S being the separation of adjacent electrodes), and the general relation between the various curves is discussed.

The accuracy of particle size determination by cumulative sedimentation methods.

By J. K. Donoghue, A.Inst.P. (*Simon-Carves Ltd., Stockport*).

Cumulative methods of particle size analysis are sometimes alleged to be inaccurate because it is necessary to differentiate the sedimentation curve in order to evaluate the size distribution. By considering a hypothetical distribution it has been shown that, provided sufficient points are obtained to enable the sedimentation curve to be plotted accurately, this differentiation does not give rise to errors. Comparative tests with the microscope and sedimentation balance on two samples composed of spherical particles confirm this conclusion.

Uniform-field breakdown in air.

By R. F. Saxe (*Queen Mary College, University of London*).

Experiments on the breakdown processes in a uniform-field gap at the minimum d.c. breakdown voltage in air at atmospheric pressure are described. It is shown that the breakdown processes consist of two phases—(1) a diffuse glow completely bridging the gap, followed by (2) a filamentary channel moving from the cathode to the anode, and bridging an 0·77 cm gap in about 3×10^{-9} s in a 13Ω coaxial system. Spectrograms of the stages of the discharge are also given. These experimental results are in disagreement with both the Townsend and the Streamer theories.